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GUIDELINES FOR THE CALIBRATION AND APPLICATION OF COMPUTER PROG--ETC(U)
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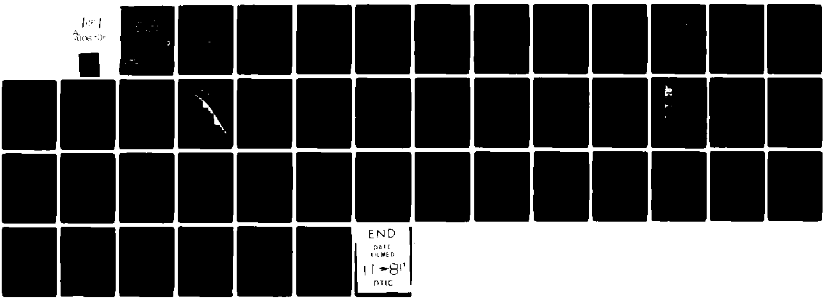

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Guidelines for the Calibration and Application of Computer Program HEC-6

The Hydrologic Engineering Center
U. S. Army Corps of Engineers
Davis, California

HEC

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GUIDELINES FOR THE CALIBRATION AND APPLICATION OF COMPUTER PROGRAM HEC-6.

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FOREWORD

This document describes methods and procedures for calibrating and applying Computer Program HEC-6, "Scour and Desposition in Rivers and Reservoirs." Data requirements for river geometry, sediment characteristics and hydrology are discussed.

Some specialized program capabilities, such as dredging, gravel mining, geometric adjustment for channel improvements, etc., are not discussed here. Persons interested in applying specialized routines are encouraged to refer to the additional publications (see references) on HEC-6 that offer details about special routines and program options or to call the HEC for assistance.

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INTRODUCTION

Computer program HEC-6, "Scour and Deposition in Rivers and Reservoirs" is a simulation model designed to analyze scour and deposition by modeling the interaction between the water-sediment mixture, sediment material forming the stream's boundary, and the hydraulics of flow. The documentation provided herein is intended to compliment the "HEC-6 Users Manual" (HEC, 1977a) and describes guidelines for calibration and application.

These guidelines suggest specific steps to follow in applying HEC-6 to analyze the following sediment problems.

a. Sediment deposits and distribution in a deep reservoir.

b. Sediment deposits and distribution in a shallow reservoir.

c. Maintenance dredging quantity and frequency.

d. Aggradation and/or degradation of natural streambed profiles.

The major steps necessary to accomplish these applications are summarized below and are described in detail in this report.

a. Comprehend the historical behavior of the stream system.

b. Develop representative data.

(1) Prepare geometric data.

(2) Debug geometric data.

(3) Calibrate n values.

(4) Prepare sediment data.

(5) Prepare hydrologic data.

(6) Establish permissible length for computational interval.

(7) Prepare flow histograms.

c. Verify the numerical model.

d. Analyze a base test condition.

e. Analyze desired alternatives.

f. Perform a sensitivity study.

HISTORICAL BEHAVIOR OF THE STREAM SYSTEM

It is essential for the modeler to first comprehend the historical behavior of the stream system. Both design of the digital model and assessment of its performance require such an understanding. The "stream system" means the water-sediment mixture flowing in and interacting with the stream channels in the study area. Historical behavior refers to the engineering time scale, not geologic time.

The study area should extend sufficiently far upstream from the problem area so that alternatives being evaluated do not produce changes to the streambed profile or the suspended sediment load at the upstream boundary. In the lateral direction, the study area should extend up all major sediment producing tributaries. Usually the location of stream gaging stations determines the limits of a study area. Hydraulic structures offer another opportunity to establish a boundary, but they are more appropriate as a downstream boundary than an inflow boundary.

In addition to geometric, hydraulic and sediment considerations, selection of the size of study area must include economic considerations. That is, all of the area over which project benefits are derived should be included within the study area. To ascertain the historical behavior of the stream system, assemble all information from office files: maps, surveyed cross sections, observed water surface profiles, aerial photographs, ground photographs, flow hydrographs, stage hydrographs, stage-discharge rating curves, water temperature, suspended sediment loads, total sediment loads, gradation of the suspended and total load, gradation of the streambed; the

location, date and size of all impoundments; the location, date and extent of all construction activities adjacent to the stream channels; the location, date, amount and material gradation for each dredging activity in the study area; land use and soil types; and prior studies.

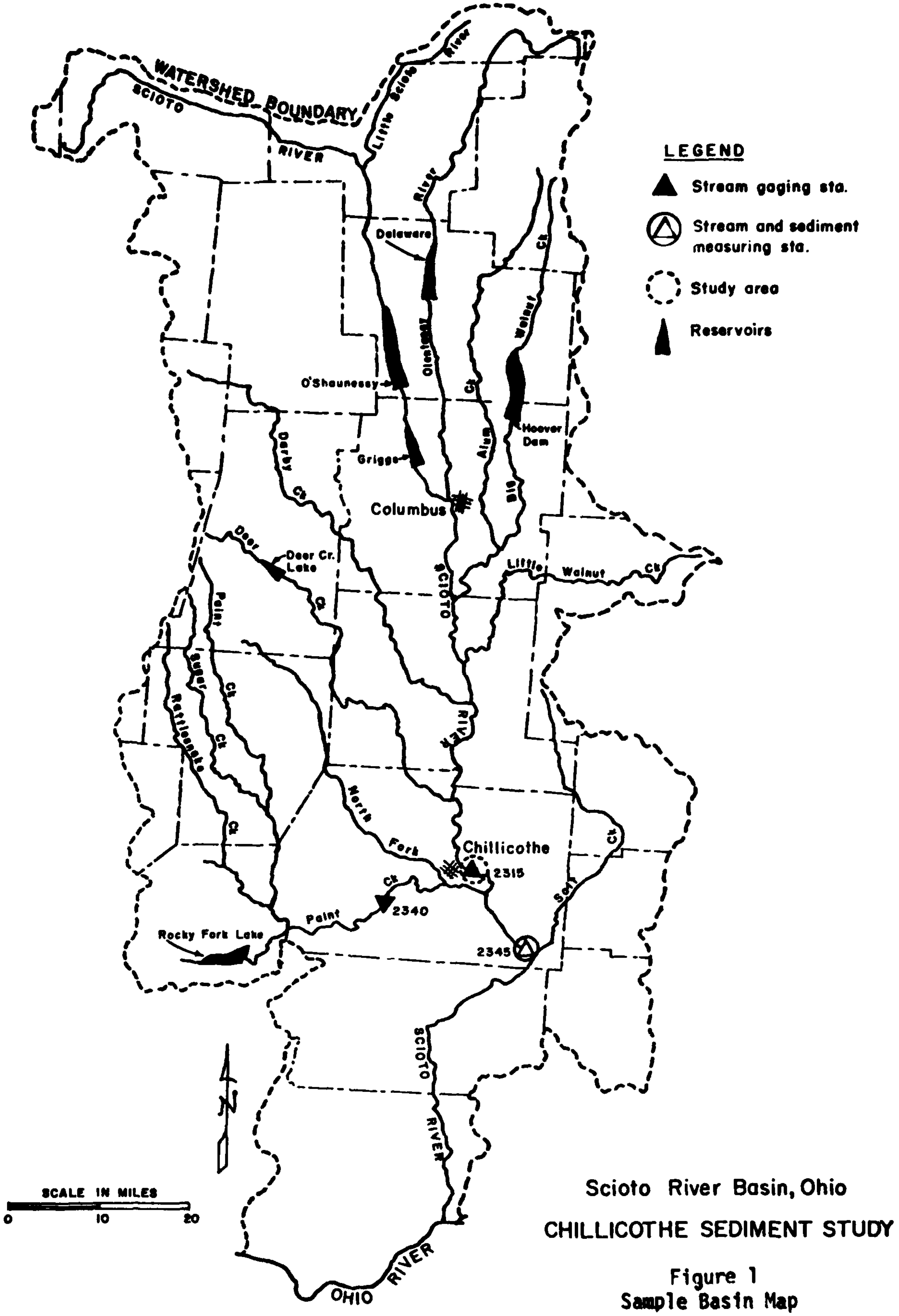
Display the above information on a study-area map(s), such as on maps like those in Figures 1 and 2. Delineate areas of adequate data. Show the availability of each type of data on a time line. Having organized and inventoried available data, begin a detailed study to accomplish each of the following tasks:

a. Establish a general knowledge about extreme events in the study area and how the system responded in terms of channel changes and amount of sediment transported;

b. Establish a general awareness of the response time of the stream system in terms of rate of movement of flood hydrographs, rate of response to changes in sediment load, etc.;

c. Establish the impact of new impoundments on the water discharge hydrograph and the sediment load;

d. Establish a general understanding of the historical behavior of the stream system - the part of that behavior that would have occurred naturally and the part which should be attributed to man's activities in the study area (land use as well as stream use);



Scioto River Basin, Ohio

CHILLICOTHE SEDIMENT STUDY

Figure 1
Sample Basin Map

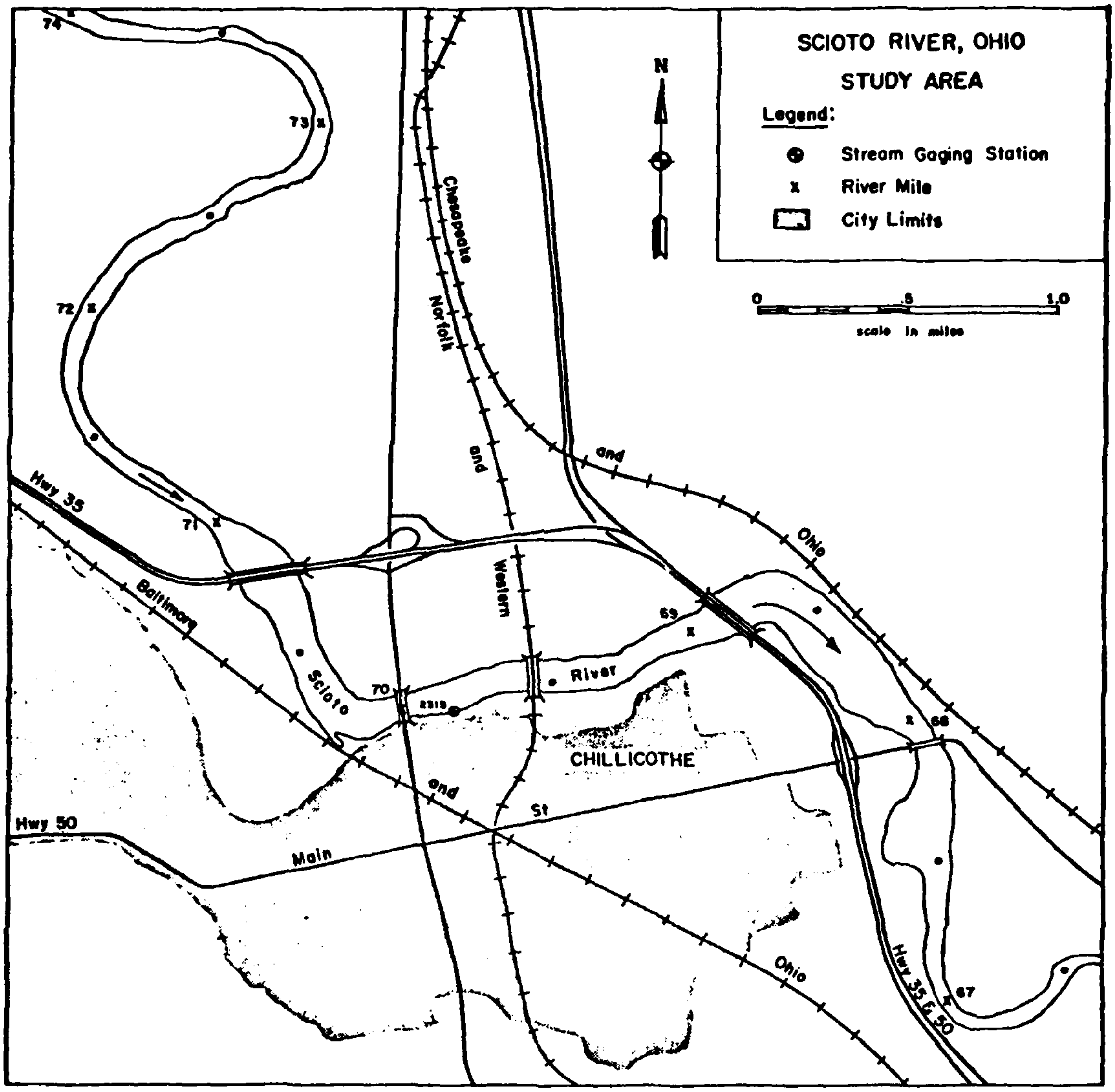


Figure 2
EXAMPLE STUDY AREA MAP

e. Locate anomalies in geometric, hydrologic, hydraulic and sediment characteristics within the study area;

f. Refine the study objectives, possible alternatives for solution and appropriate analytical approaches; and

g. Identify missing data which can be supplied only by additional field measurements or field reconnaissance.

Be prepared to make a complete study of all information for each one of the above objectives and to modify those objectives to fit each individual problem.

View the study area with someone who is intimately familiar with it. Particularly, note all locations where scour or deposition occurred and the stream did not return to its original cross section or alignment. Locate and date each cut-off (natural or man made), each encroachment, each levee, each diversion and/or each bifurcation. Note overbank areas which flood first and locate their natural levees.

Study the streambed and banks to locate rock outcroppings or other geologic formations which will resist scour. Study the grain size of sediment on point bars to detect where sudden changes occur in the surface. Note any sand deposits on overbank areas. Of particular interest are locations where the gradual change from coarse to fine particles, in the downstream direction, is interrupted by a sudden change which persists in the downstream direction.

Determine as much information as possible about bed roughness, and particularly about changes in bed roughness that occur along the stream or that may occur as discharge changes. Numerous vortices may accompany dunes, but visual characteristics of the flow usually do not provide sufficient evidence to determine other bed forms.

DEVELOPMENT OF REPRESENTATIVE DATA

Specific input data requirements are presented in the HEC-6 users manual (HEC, 1977a). This section addresses the problem of developing representative data.

Representative data are not necessarily the averages of many samples. Representative geometry preserves channel width, depth, and roughness and allows the digital model to transport sediment with changes in bed elevation which match prototype observations. The representative inflowing sediment load preserves both volume of sediment and rate of sediment inflow at the upstream boundary of the study area. The representative bed gradation and size distributions of sediment data allows the digital model to transport observed sediment discharges while producing observed changes to the bed elevation. Representative water discharges include flow rate, and to a lesser extent, volume rate of movement and amount of attenuation of flood hydrographs as they move down the system. Having flows match the appropriate flow duration relationship is extremely important, (i.e., representative flows for the calibration period are those which occurred during that period, whereas representative flows for the study period are those producing the long-term flow duration curve). Beginning with geometric data, procedures for developing representative data are suggested. These are by no means "all inclusive guidelines" but they stress the most important characteristics of the real physical system which should be preserved.

Geometric Data

Identify and locate all major streams and reservoirs on a basin map (Figure 1), and a study-area map (Figure 2).

Mark the boundaries of the study area on the best available map. One should use U.S. Geological Survey topographic maps, Corps of Engineers topographic maps, or other agency maps that provide the most detail of the relief of the area. In the case of reservoir studies, shade the original channel, and outline the reservoir surface area at the bottom of conservation pool contour. Mark and identify pertinent features such as urban areas, recreation sites, harbors, levees, pumping plants, etc., that border the original channel. Mark all locations where rock outcrops cross the channel. Locate the dam axis on the topographic map.

Plot the streambed (thalweg) profile from field data (or use map contours if field survey data are not available), Figure 3. It is useful to mark the locations of pertinent elevations. This profile will serve as a base sheet for plotting water surface profiles and future streambed profiles later in the study.

Starting at the downstream end, locate cross sections on the topographic map. If surveyed sections are already available, transfer them to the study-area cross-section map, Figure 4. Otherwise, position sections at major changes in bed profile, at points where channel or valley width changes, at tributaries which are to be included in the study, and at all pertinent points where calculated results are required. Be sure to extend the geometric model sufficiently far upstream from the reservoir area so it will be beyond any backwater effects. Assign an identification number to each cross section; river miles are preferable and miles above the dam are the next choice. Avoid arbitrary numbers because they fail to convey descriptive information.

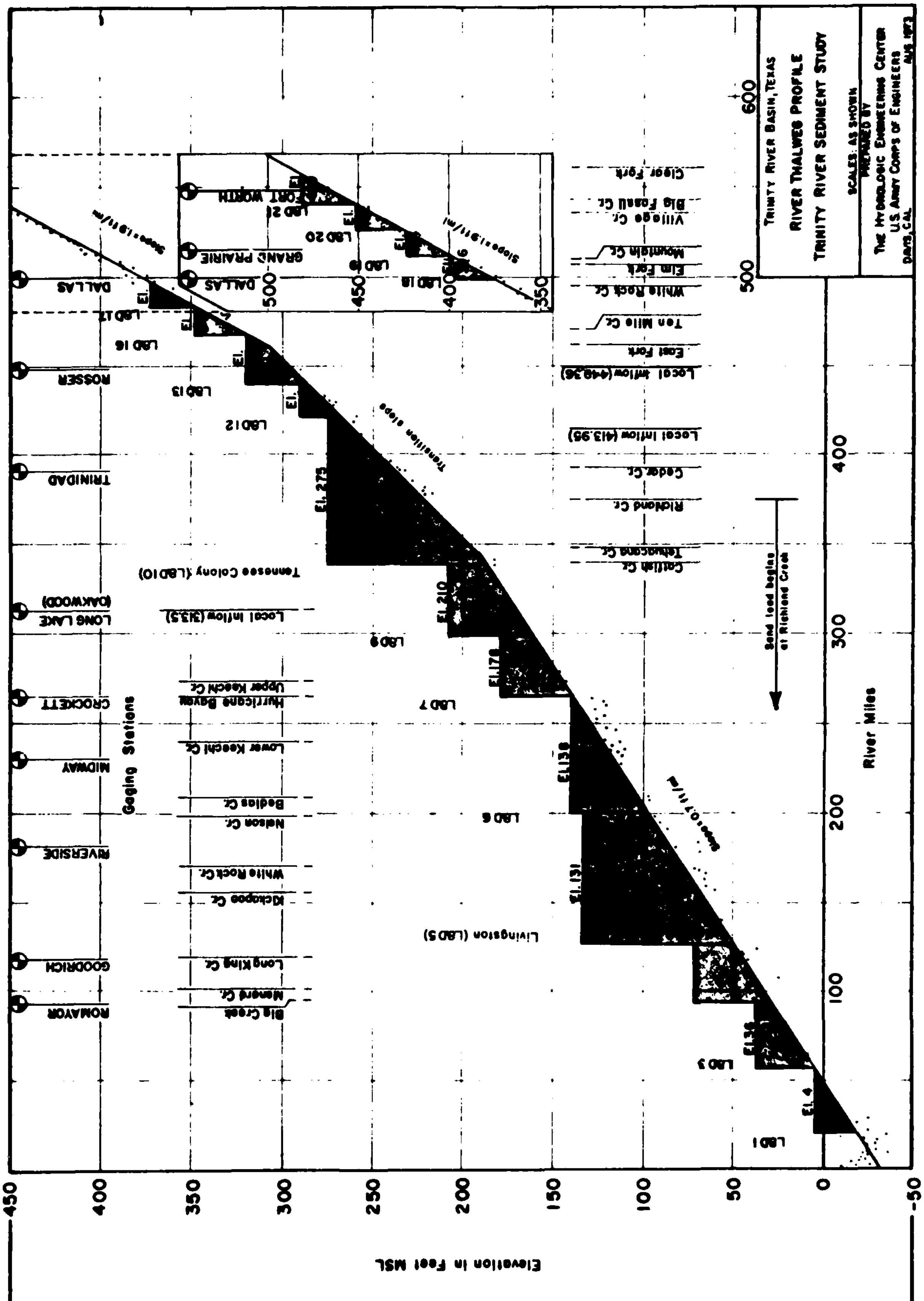


Figure 3 River Thalweg Profile

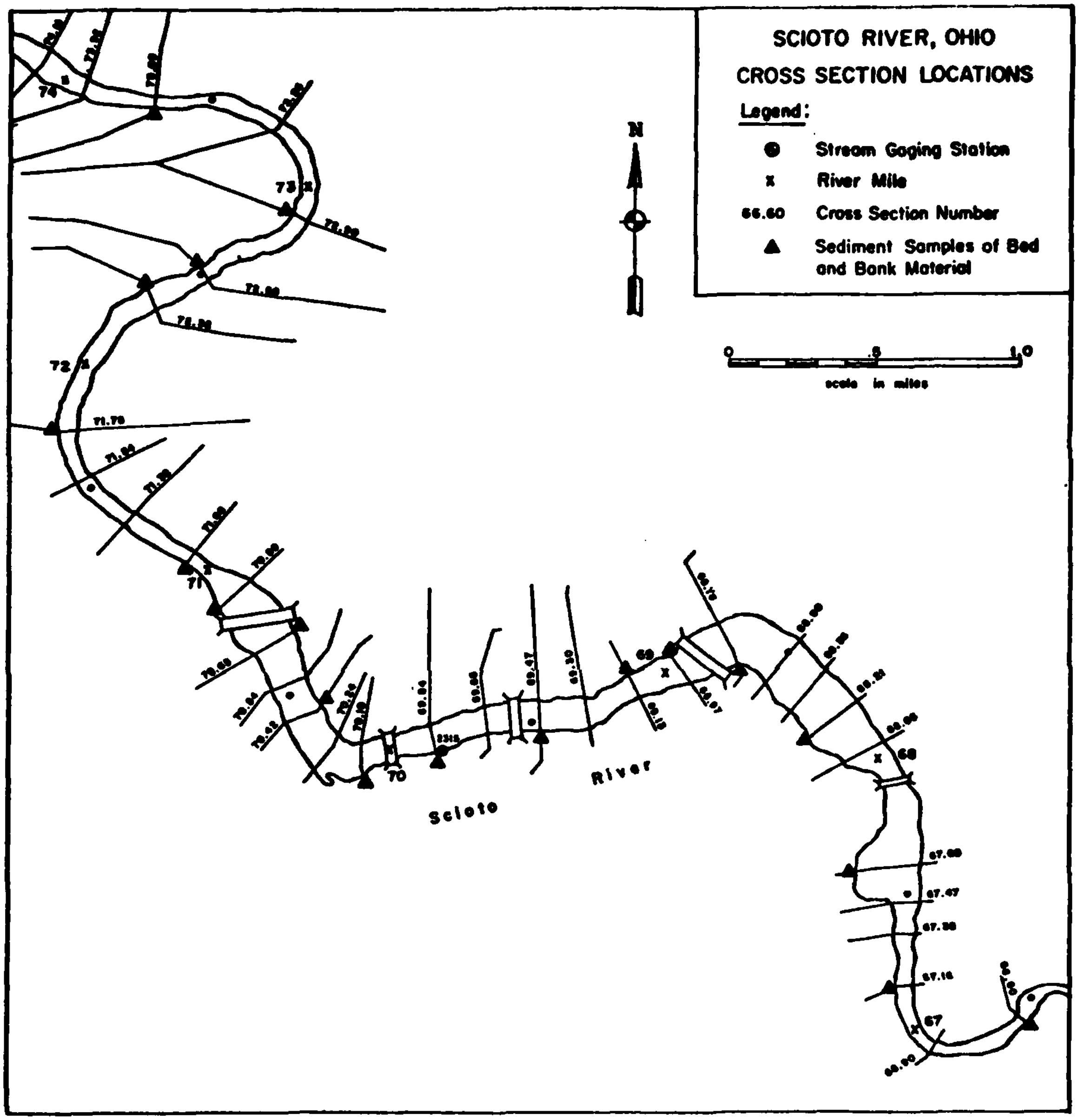


Figure 4

Study Area Map with Survey Cross Section Locations

Avoid locating cross sections too close together. The shorter the distance between sections, the shorter the computation interval has to be in HEC-6. Short computation intervals require more computer time and, therefore, should be avoided in long period studies. Methods for establishing proper reach lengths and computational time lengths will be discussed in a following section.

It is very useful to code and execute a few sections as a test reach first, prior to coding an entire problem. Mark all reach lengths on the map to show the flow alignment which is anticipated. Plot the cross sections and mark left and right channel stations, as in Figure 5. In a reservoir study, it is also useful to plot various anticipated pool elevations.

Assign the maximum limits of the movable bed to the right and the left side of the channel portion of each cross section, Figure 5, and see H-Card description in Users Manual, 1977a. Typically this will be just inside the left and right channel stations. Only the coordinates between these limits will be subject to scour and deposition; overbank areas beyond the left and right channel boundaries are treated as a fixed bed.

Mark the top of rock elevation for geologic formations on any cross section where it occurs at the bed surface or within the top 10 feet of bed materials. The computer program requires an elevation for "model bottom." If it is not prescribed in the input data, the program defaults to 10 feet below the thalweg. Erroneous answers for sediment transport and bed locations may result if an existing hard-bottom geologic control, such as a rock outcropping, is not coded for the computer program.

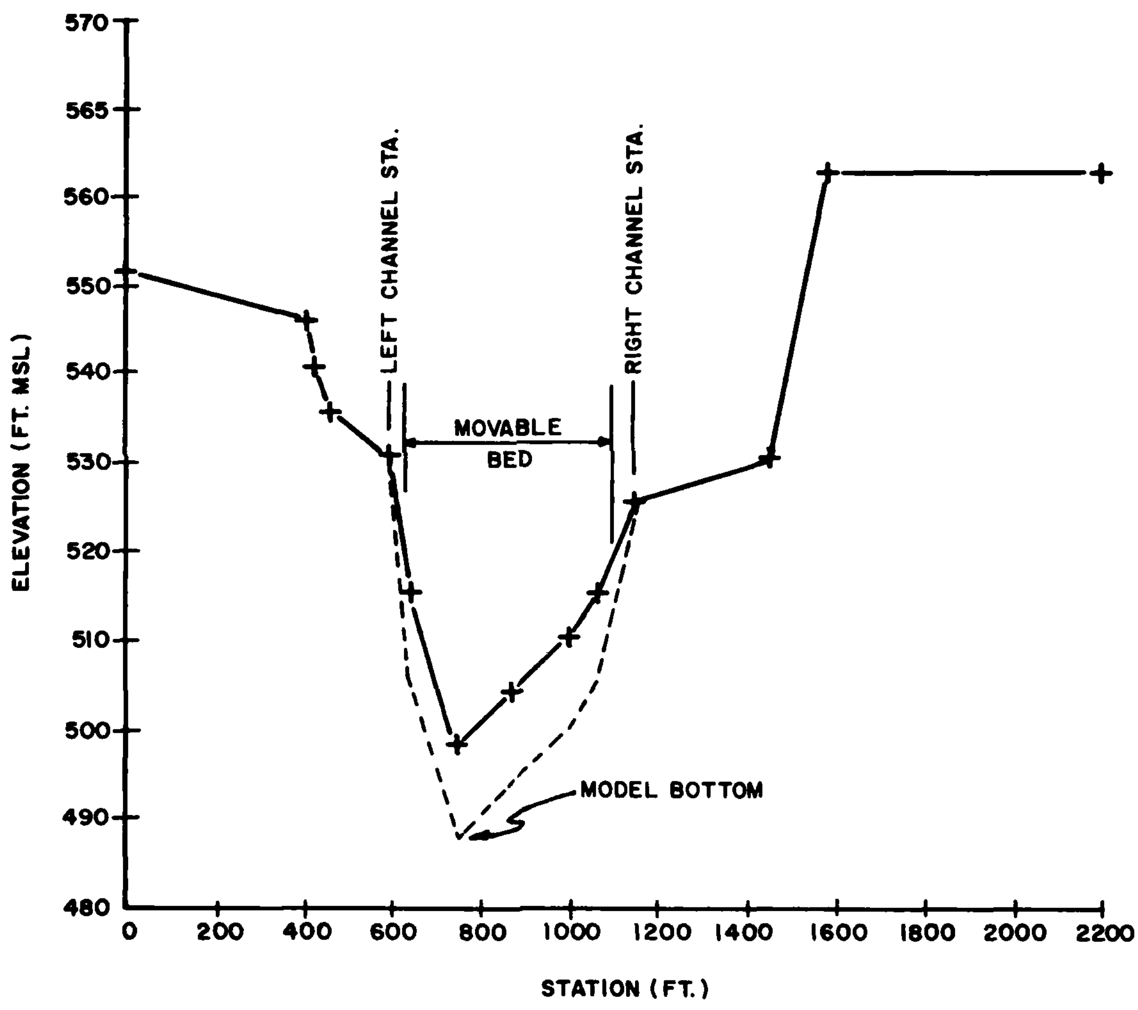


Figure 5

Example Cross Section

Debugging Geometric Data

Movable streambed profile calculations are much more sensitive to errors in boundary geometry than are fixed-bed water surface profile calculations; consequently, more care is required to debug geometry than is typical for fixed-bed water surface profile models. A cross section which is too wide or too deep will show up as a point of deposition. On the other hand, one which is too small will exhibit a tendency to scour. Not only will the erroneous section be affected, but calculated results will be incorrect at sections upstream and downstream from it. Geometric data errors, therefore, are difficult to locate when the program is executing in the movable-bed mode, and the first step in debugging the geometric data is to run the model in the fixed-bed mode.

In order to run HEC-6 in the fixed-bed mode, one needs to remove all of the sediment data cards (i.e., the T4-T8 cards up to, but <u>not</u> including the $HYD card) from the input deck. Removal of the sediment data cards signals the program to compute steady-state water surface profiles only, and not to attempt any sediment computations. This allows users to calibrate and verify the geometric and hydraulic portions of the study separately from the sediment portions. This is a very critical first step because validity of subsequent sediment computations is dependent upon having an accurate hydraulic description of the system as well as representative sediment data.

Selection of n Values

Appropriate values for Manning's n should be determined by running the computer model in the fixed-bed mode. During the analysis of geometric data

and calibration of n values, several computer runs will usually be required. This is necessary to compare calculated water surface elevations with observed water surface profiles and with established rating curves; and thus, allows the adjustment and determination of the proper values to use for Manning's n.

Careful consideration should be given to the selection of n values. Changing n values with distance should be justified based on changes in channel appearance or sediment size. Avoid changes where the only reason is to reconstitute an observed stage (Vanoni, 1977). Oftentimes, it is more logical to approximately reconstitute the stages at several gage locations over a long reach using a constant n value for that discharge, than it is to change n values at each gage in order to exactly match the observed stage. Also, it is suggested that n values may vary with discharge (Figure 6), that is, the bed form in alluvial rivers often changes during the passing of a

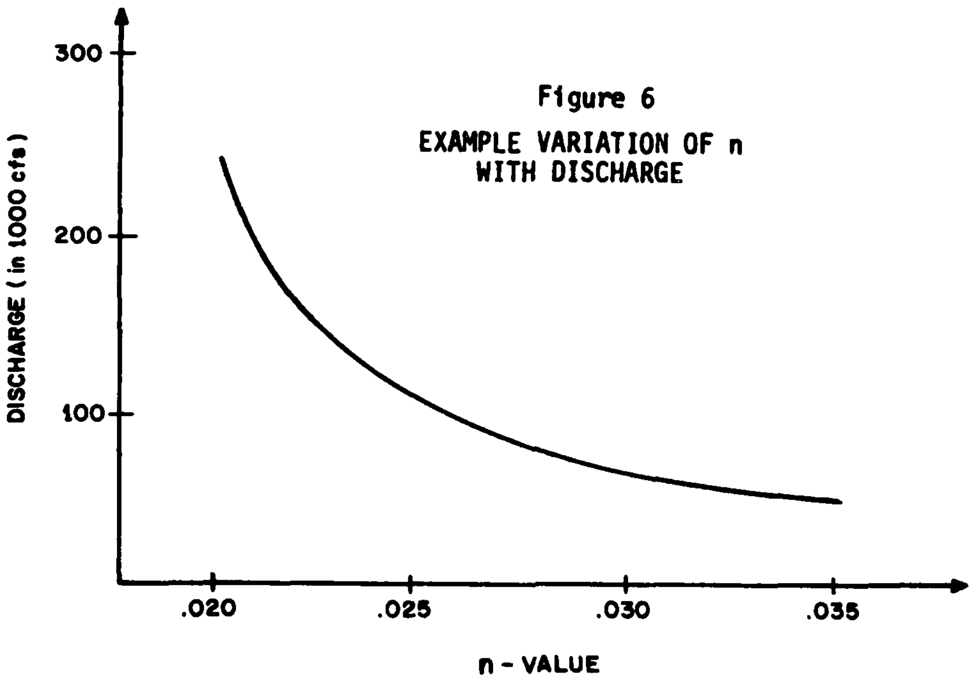


Figure 6
EXAMPLE VARIATION OF n
WITH DISCHARGE

flood event. As yet, it is not possible to accurately calculate when such changes will occur, but until a theoretical basis is developed, one should at least acknowledge the change by associating n values with water discharge if field data for the particular river support such a variation.

Calibrating n values as described above implies that a fixed-bed model is satisfactory through a range of flows, including floods. The technique assumes that the entire bed of the river is stationary and does not move during a flood event. This assumption is valid over long distances (several miles) whereas it may not be valid at a single section. Also, the technique assumes the channel is well defined. Some other procedure may be required in areas where each flood forms its own channel such as on alluvial fans.

Begin the analysis of geometric data and calibration of n values with natural river conditions, and select three water discharges to check model performance. One of these discharges should be an extremely low flow; the lowest in the hydrographic record during the anticipated study period is acceptable. Extreme changes in velocity, depth or width from one section to another may reflect a data error and should be checked.

The second discharge should be the "bank full" flow. The left and right top-bank profiles are usually very irregular. In movable-bed calculations it is extremely important to specify bank elevations that are "representative" of prototype conditions since successful simulation of the prototype <u>requires</u> flow to "spill" onto flood plains at the proper discharge. This will require assigning bank elevations which are representative for the reach rather than just accepting point values from a field survey. To check, plot both the bank elevations and the calculated water surface profile on the profile sheet.

Smooth out any irregularities which fail to be representative of the reach by modifying input geometry.

The third test discharge should equal the maximum value anticipated in the hydrograph of flows for the study. Usually this discharge profile approximates the valley slope more closely than the channel slope. Therefore, plotting it on the profile work sheet gives the opportunity to compare changes in slope with valley width and thereby insure that flow controls are actual and not just data errors.

Sediment Data

Preparation of accurate sediment data and development of a representative inflowing sediment load curve are essential. The overall objective in preparing sediment data for reservoir deposition studies is to develop a relationship between the water discharge and the inflowing sediment load which depicts the long-term, average sediment yield. In river studies the overall objective is to establish the amount of sediment load that accompanies river flows and determine the proper size distribution and character of the bed material.

The most common approach is to plot water discharge versus total sediment load on log paper as shown in Figure 7. These plots usually exhibit a log cycle of scatter. The representative load is one which produces the proper annual volume of sediment when integrated with the water discharge hydrograph for the year in question, as depicted in Figure 8. Adjust total load until a representative curve has been established.

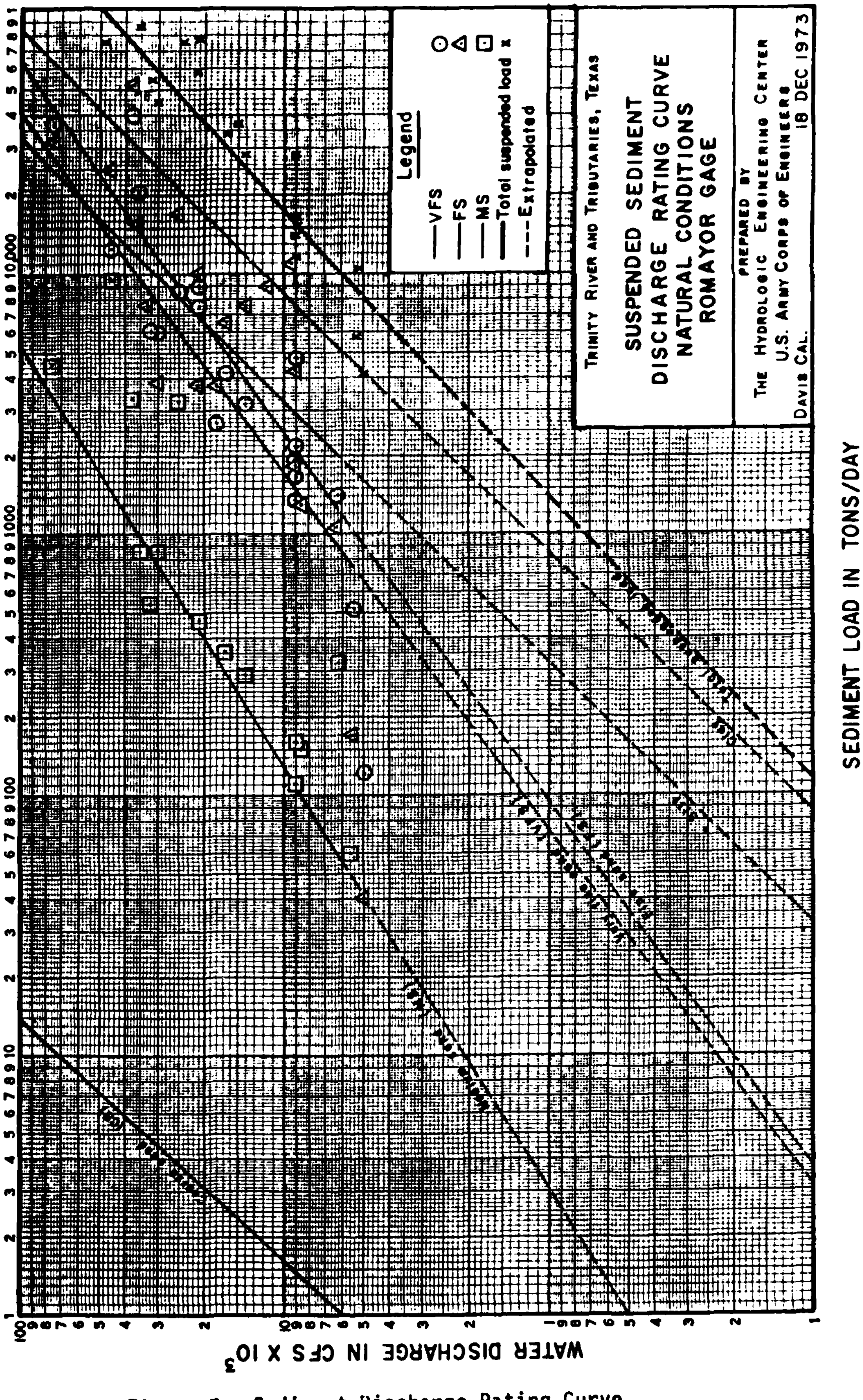


Figure 7 Sediment Discharge Rating Curve

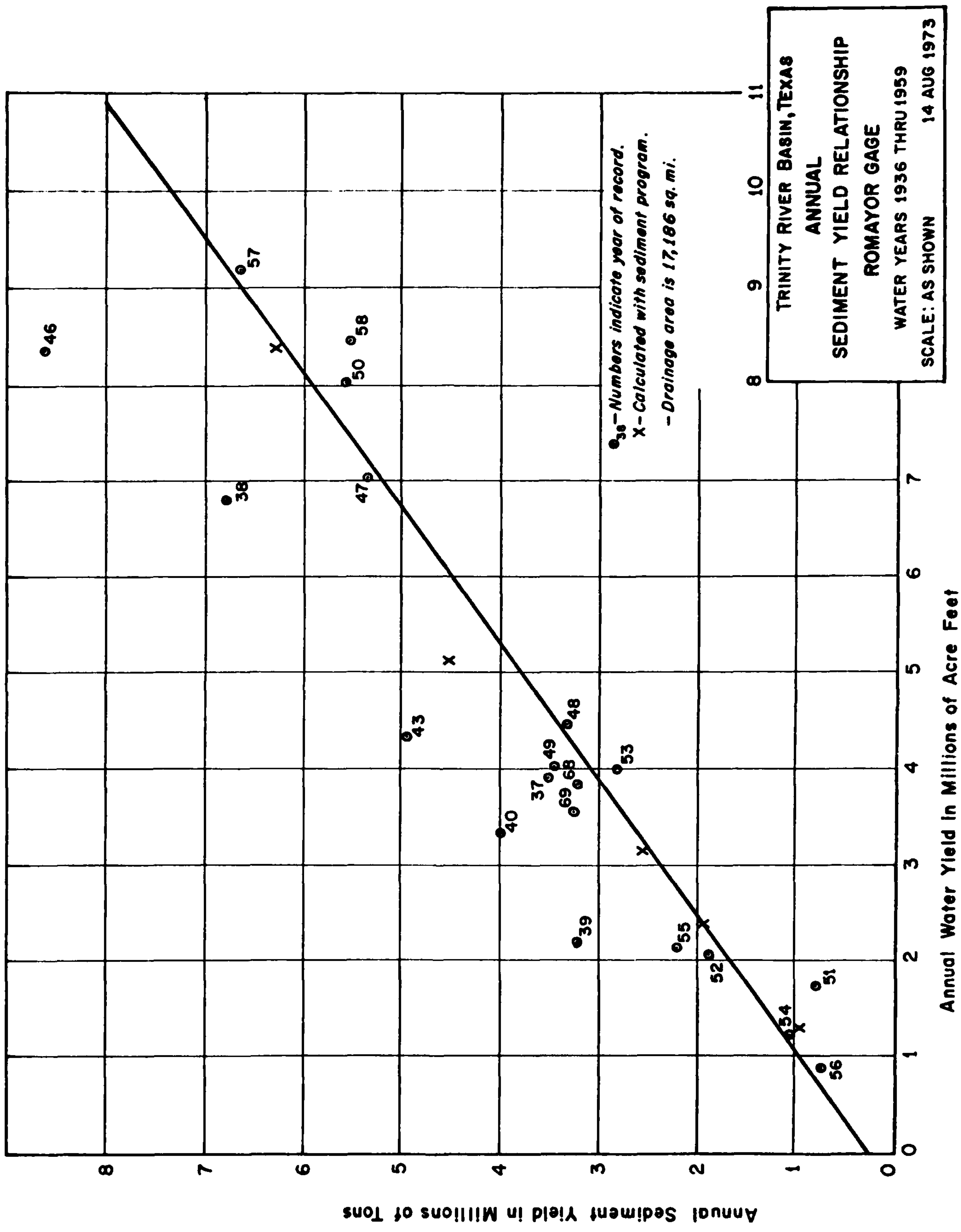


Figure 8 SEDIMENT YIELD CURVE

After the representative total-load curve is established, individual grain size loads must be studied. Select only those suspended sediment samples for which gradation data are available and calculate the clay load, the silt load and the sand load in each sample. Plot each of these loads separately to form three single relationships: one for clay, one for silt, and one for sand and larger particles as shown on Figure 7.

Calculate the fraction of the total load which moves as clay, as silt and as sand and plot these values as a function of water discharge as shown on Figure 9.

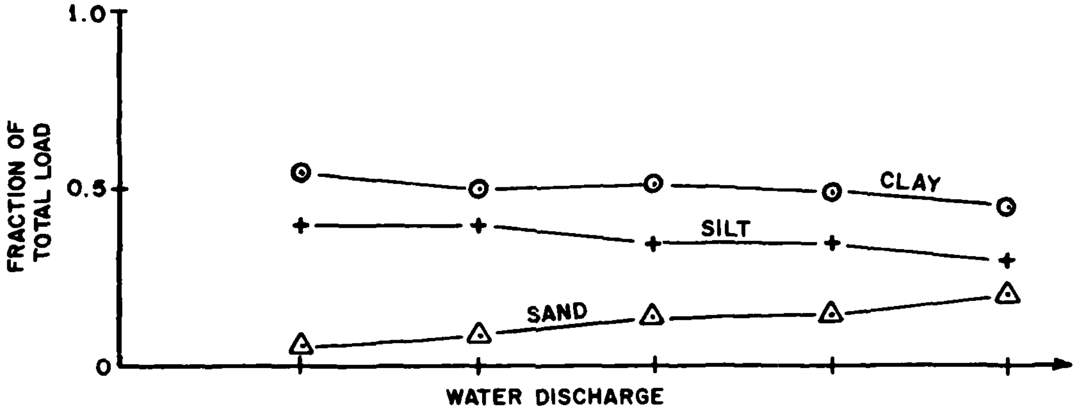


Figure 9. FRACTION OF TOTAL LOAD BY GRAIN SIZE CLASSIFICATION

Using both suspended load and bed material gradation as guides, subdivide the sand and larger-size classes into class intervals: very fine sand, fine sand, medium sand, etc. In river studies where silt and clay remain in suspension these sizes can be neglected in favor of the bed material sizes. In reservoir studies the silt class should be subdivided also, but without suspended load gradation curves this is not possible.

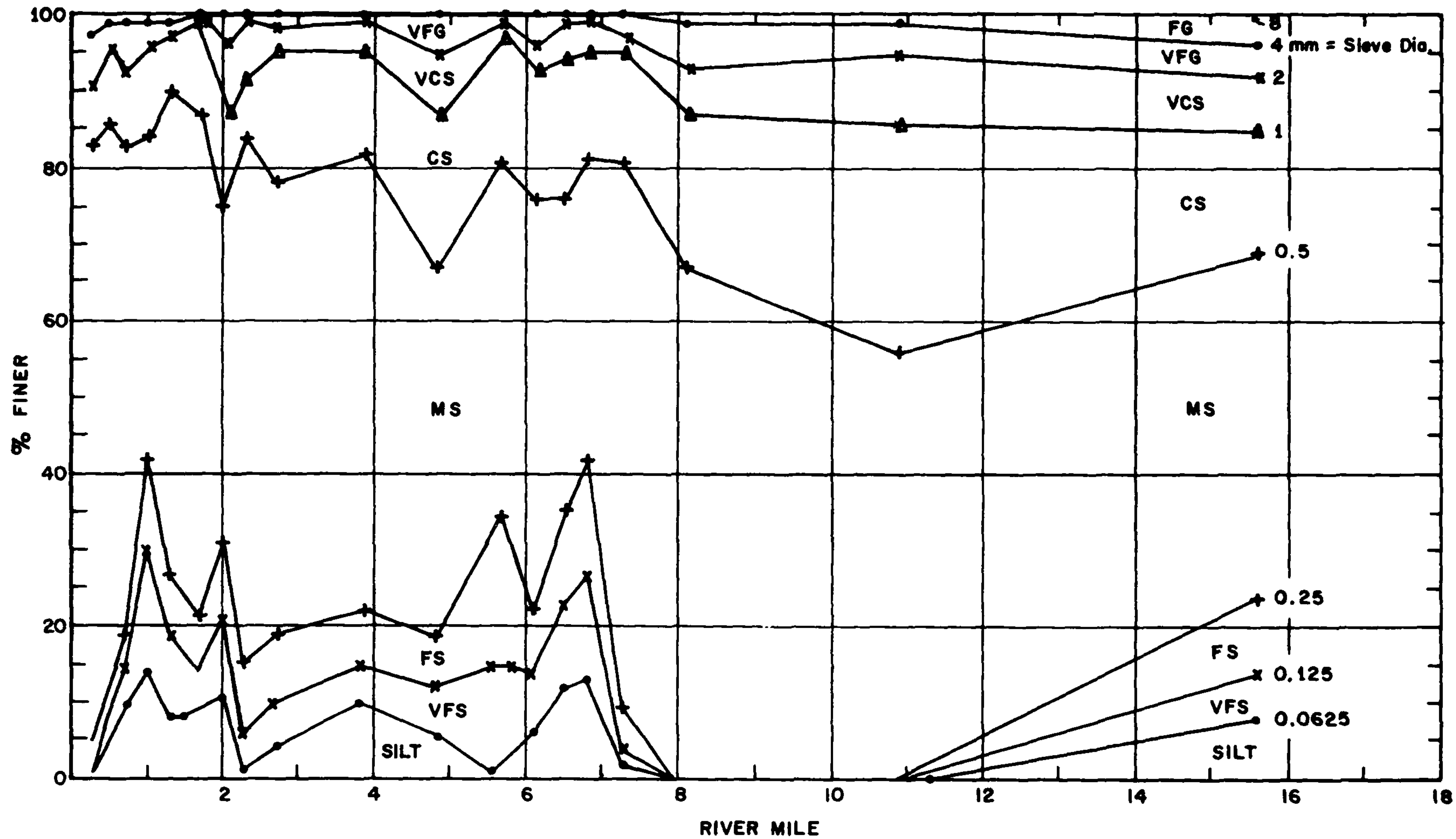


Figure 10. Example of Profiles of Bed Sediment Size, Big Sandy River, Huntington Dist., C.E.

Once representative inflowing sediment load curves have been identified for all size classes, bed material gradation curves must be developed. Figure 10 shows profiles of grain size gradation versus river mile. Plotting the data like this will allow the user to analyze the results for trends in grain size changes with respect to distance along the river.

An alternative is to have the program calculate the bed gradation which is required to transport the inflowing sediment load. This approach (IBG option in field 3 on card I1) assumes the information about the gradation of the inflowing load is better known than the gradation of bed material. This option can be used when information about the bed is not available. By using this option the program will calculate the sediment gradation in the surface layer based on the transport capacity required to just transport the inflowing sediment load with no scour or deposition, if possible. (Users still need to provide the proper number of N cards and should not use the IBG=3 option on the I1 card when restarting a run with O cards).

In reservoir deposition studies, where silt and clay dominate the volume, detailed calculations of bed gradation are not necessary. Given an approximate value, the program will calculate the bed gradation along with changes in cross section elevation.

Hydrologic Data

Hydrologic data consist of the following items:

a. Inflowing water discharges for the mainstem and for all local inflow points.

b. The stage hydrograph, rating curve, or operating rule giving water surface elevation at the downstream end of the model.

c. Temperatures for the inflowing water discharges (see Vanoni, 1977, for explanation of importance).

The calculation technique in HEC-6 requires that the discharge hydrograph be converted into a discharge histogram as shown in Figure 11. The histogram approximates the hydrograph with a sequence of steady flow events, each of which has a duration of a number of days (e.g., 10,000 cfs for 8 days, 7,000 cfs for 7 days, 2,700 cfs for 24 days, etc.) called the "computation interval."

Establishment of Computation Intervals

The length of the computation interval is critical. If too short, enormous amounts of computer time will be required. If too long, all calculated results will be incorrect. The first step in preparing hydrologic data is establishing the proper computation interval for the problem at hand. The computation interval varies with water discharge, with the rate of sediment inflow, with cross-section spacing and with the transport function selected for the study. At this point the inflowing sediment load and cross-section spacing are known. The desired transport function should be selected and the time interval should be selected using the following procedure.

Three test discharge hydrographs should be coded: bank full, low flow and peak flood flow. (These can be the same discharges that were used for the n_r value calibrations earlier.) For example, the bank-full sample test

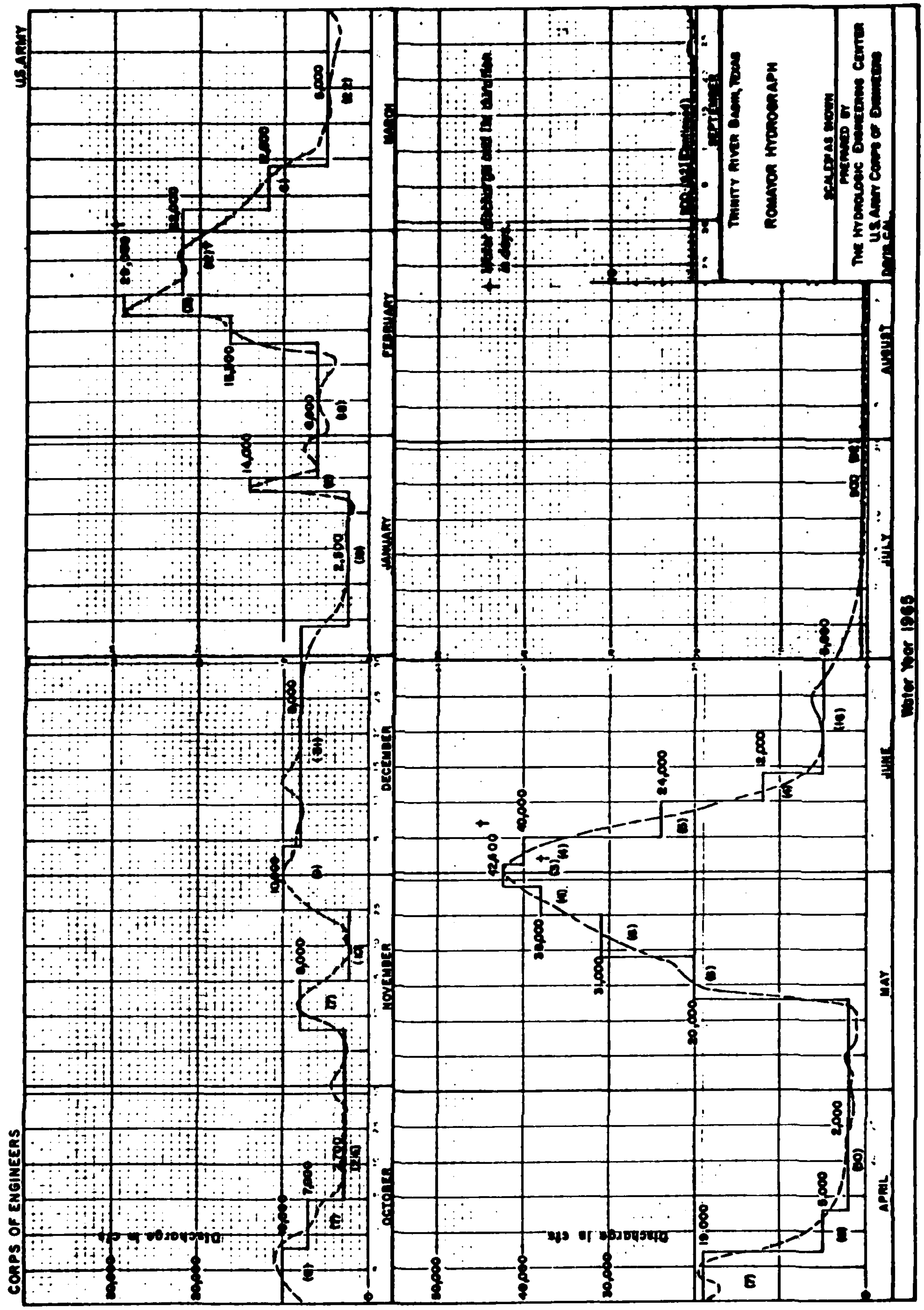


Figure 11. Water Discharge Hydrograph

hydrograph would include: 5 constant discharge events at 1-day each, 5 more at the same discharge with a 2-day computation interval, followed by 5 more events at the same discharge with a 3-day computation interval followed by 5 more events at 5-day intervals (See Figure 12). Results from this series of computations will indicate the most desirable computation interval to use during flows that are nearly bank full. Be sure to reinstall all the sediment data cards and run the program in the movable-bed mode once again. Figure 11 illustrates the resulting test histogram with constant discharges and several different time intervals.

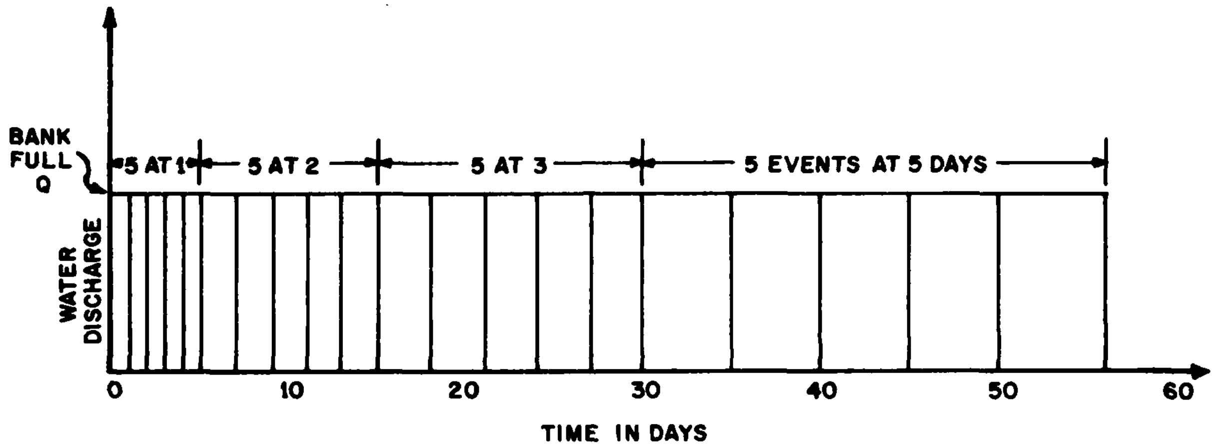


Figure 12. A BANK-FULL DISCHARGE TEST HYDROGRAPH

The computation interval will usually exceed one day on major rivers. Therefore, coding five discharge events at one day each lets initial instabilities dampen out before the critical test interval is reached. Request "B-level" printouts for all sediment computations and none for hydraulic computations, (i.e., leave column 5 blank and type a B in column 6 on all the * cards). Code a constant downstream water surface elevation from a "natural conditions" discharge rating curve on the R cards.

Scan the B-level printout for day one to locate the cross section having the largest change in bed elevation. Flag that section and plot the value

for bed change as a function of time as shown in Figure 13 (i.e., the bed change at the flagged section for all remaining days in the test) using the remaining B-level printout. Note that the bed changes printed are cumulative from the beginning of the run.

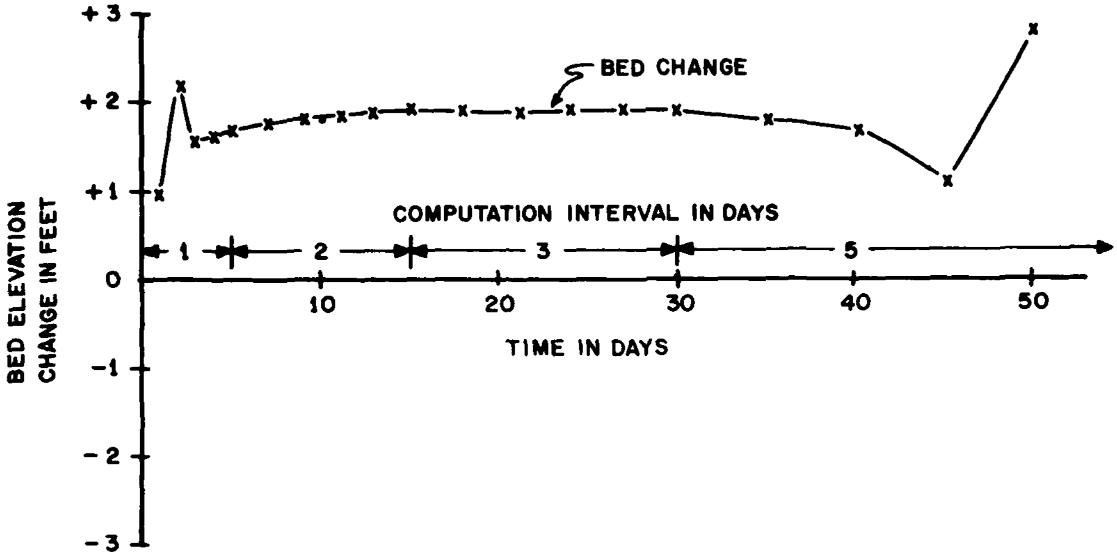


Figure 13

Model Response To Length of Computation Interval
For a Selected Cross Section

The resulting graph should approach a smooth curve, as is illustrated between 10 and 30 days in Figure 13. When it does, the range for the stable computation interval has been established (e.g., 2 or 3 days in Figure 13). Oscillations are usually evident at the beginning of a run, because of poor initial conditions, but they should dampen out. When the computation intervals chosen for the test discharge become too long, oscillations will resume as illustrated between days 40 and 50, in Figure 13 above. If initial oscillations do not dampen out, even the first computation interval is too long.

Divide all computation intervals by 10 and make a second run. Repeat this procedure until a stable interval has been determined. Note: HEC-6 does not simulate the movement of dunes; therefore, saw-tooth bed elevations at a section indicate that numerical oscillations are occurring and the computation interval should be reduced.

Scan the printout at the end of the stable computation interval (i.e., day 30) and flag the cross section having the second greatest bed change, either plus or minus. Plot those changes on the above graph also. Repeat this process for several (four or five) other cross sections and redefine the stable computation zone, if necessary. At this point, the stable interval has been bracketed. One final test remains. Scan the sediment load passing each section using output for the last discharge event within the stable computation intervals (i.e., day 30 in the previous example) for the following:

a. Silt and clay should not deposit in the channel under natural river conditions. Any cross section which exhibits a reduction in load passing through that section should be carefully checked. The cross section may be too large or a false channel control may exist downstream.

b. The sand load should approach a steady value, equal to the inflowing load, from section to section rather than the erratic variation associated with the calculation at the first event. Sections which have very little transport capacity should be checked for errors in cross section, reach length, *n* values, limits of movable bed or, perhaps, bed material gradation.

If the model performance simulates the behavior you would expect in the prototype in all respects, the computation interval along with the other several parameters have been determined. Otherwise, determine what is causing the questionable performance. For example, excessive fill may mean the limits of movable bed are too narrow or the natural levee is too low. If the prototype is depositing sediment above the overbank elevation, expand the movable-bed limits to include the overbank. If water is spilling onto the overbank in the computer model but that area is not effective for conveyance in the prototype, raise the natural levees. If excessive scour is indicated by the computed results, it may mean the prototype has either an armored bottom or non-erosive or rocky bottom and is resistant to scour. This test procedure is somewhat inconclusive because the problem may go away when a flood hydrograph is analyzed, but it may point to potential problems which should be reconciled before adopting the final computation interval at that discharge.

Proceeding to the final step, code a longer test hydrograph, using the computation interval just determined and plot the history of bed elevation changes on an extension of Figure 13. The results should plot a smooth curve and approach a steady value. Scan the printout for any bed changes other than those previously identified. It will be rare when any turn up, but if they do, add this (these) section(s) to the graphs in Figure 13. When all sections remain stable for these steady-flow tests, the best allowable computation interval has been determined. Plot that interval versus the steady discharge as is shown in Figure 14.

Repeat the above for the other two discharges and add those points to Figure 14. By this time, one will have developed sufficient insight into

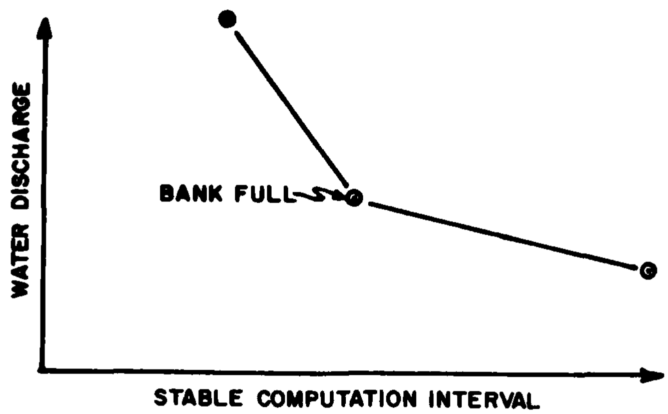


Figure 14
VARIATION OF COMPUTATION INTERVAL WITH Q

model performance that the testing will be accomplished quickly. Connect the points in Figure 14 to determine an acceptable computation interval for the various magnitudes of flow found in your flow histogram.

When instabilities are not detected until after the water discharge hydrograph has already been coded and punched on cards, the optional X card can be used to shorten the computation time without having to repunch entire sets of *, Q, W cards. Readers interested in using this option should refer to the Users Manual (HEC, 1977a) for detailed instructions.

Preparing Flow Histograms

The three main points to consider in developing flow histograms are:

a. Preserve the total volume of water in the hydrograph.

b. Preserve the total volume of sediment which was transported during the hydrograph period.

c. Make the computation intervals as long as possible and still preserve computational stability (HEC, 1977b).

There is, usually, a strong correlation between the annual volume of water that passes a gage and the annual sediment yield of that basin, recall Figure 8. The rate of sediment movement, called sediment load, is not a function of water volume, however. It is a function of water discharge (Figure 7), and the availability of sediment material. In many cases, three-quarters of the annual sediment yield will be transported in less than one-quarter of the year. Therefore, it is necessary that all histograms contain the flood peaks.

Adopt a "test year" and process the generated histogram. Verify that the model response is proper before proceeding with the remaining years.

MODEL VERIFICATION PROCEDURES

Prior to using a numerical model such as HEC-6 for the analysis of projects, the model's performance needs to be evaluated. Evaluation normally consist of two phases of testing: calibration and verification. As we have already discussed in a previous section, calibration is intended to make computed results as accurate as possible. Measured or observed values from the prototype are compared with computed results to pinpoint input data deficiencies or physically unrealistic coefficient values. Model parameters are adjusted accordingly to improve the solution. Calibration, however, does not mean the use of physically unrealistic parameters to force a poorly conceived model into satisfying prototype data. If there is a discrepancy between model results and calibration data then either there is something wrong in the physical realism of this model (a model deficiency as a result of limiting assumptions) or there is something wrong with the measured data (a data deficiency). Therefore, if calibration cannot be accomplished through the usage of physically realistic parameter values, the measured prototype data should be checked for possible errors and then the entire model (input data and limiting assumptions) should be examined, coding problems should be checked, and boundary specifications should be examined. Once calibrated, a model needs to be verified.

Verification is concerned with checking that the calibrated model continues to describe the prototype behavior for events not used in the calibration process. Therefore, after the n values and inflowing sediment loads have been calibrated, a hydrograph of historical flows should be analyzed to ascertain that the calculated water surface and bed profiles duplicate observed values during that same period of time. Water surface elevations of $\pm$

0.5 foot are usually satisfactory in natural rivers. Profiles of the average bed elevation may exhibit no correlation, but cross-sectional area changes should correlate with prototype behavior.

Two types of graphs should be plotted for the verification period. The first is the calculated water surface elevation hydrograph, e.g., Figure 15.

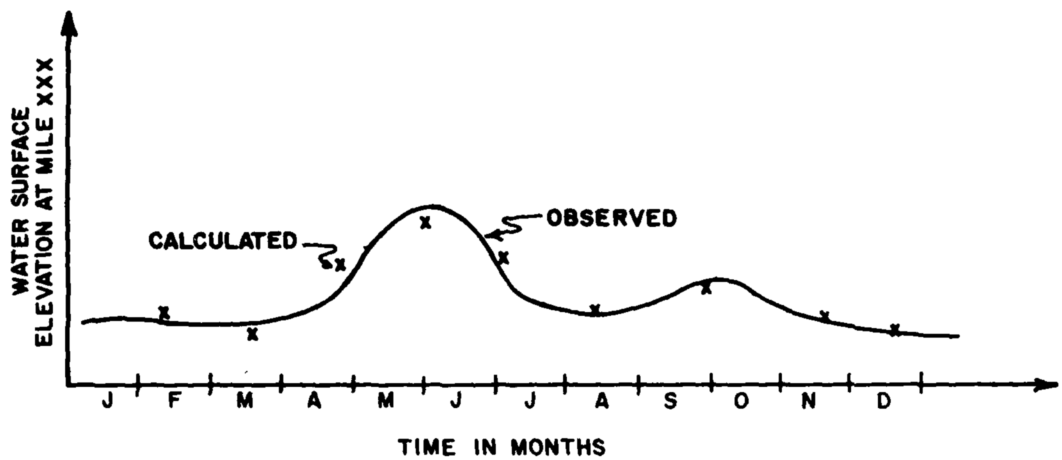


Figure 15

EXAMPLE PLOT OF WATER SURFACE
ELEVATIONS DURING VERIFICATION

The verification period may extend for several years. If so, select only three or four values per year to plot. Plot these calculated water surface elevations at all gages in the study area as well as the observed elevations that occurred at the same points in time. Evaluate model performance by computing the mean value of the absolute values of error. Of course, the lower the error, the better the performance. Unfortunately, performance quality is defined by problem-specific characteristics and will probably differ from problem-to-problem. Good engineering judgment should be used to determine when the model's performance is, in fact, satisfactory or requires additional calibration.

A second method of displaying simulation results is the trend plot, as shown in Figure 16. To obtain calculated water surface elevations for the desired discharges, place those discharges in the histogram with a very short duration (say 0.01 days) periodically. This will cause a water surface profile to be calculated but, because of the short duration, sediment movement and, therefore, changes in bed profile will be negligible. One can then compare calculated and observed changes with time in rating curves at selected gages. Typically, the water surface elevations for a low flow and bank-full flow are monitored in this fashion.

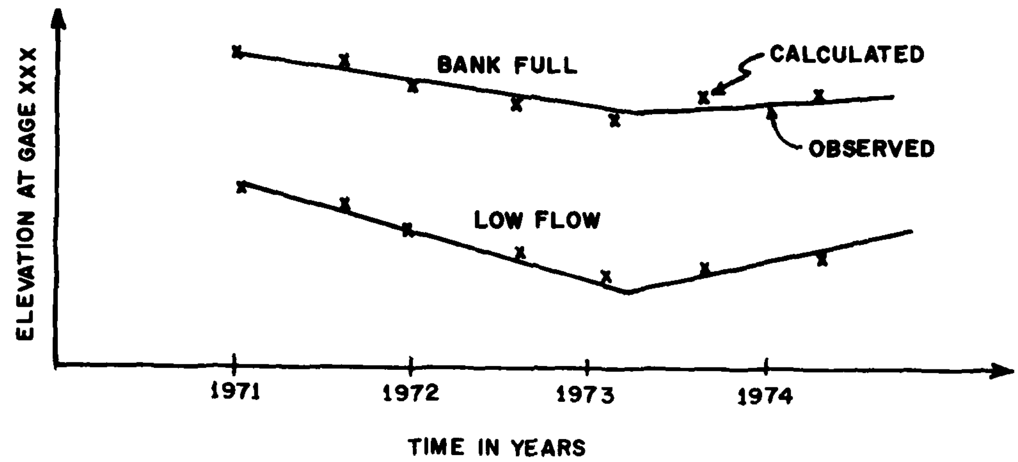


Figure 16

EXAMPLE WATER SURFACE TREND PLOT

The above trend plots illustrate a prototype river which is degrading up to 1973. Model results, the "x's", correlate well with the observed elevations which indicates good model performance.

If the calculated results do not follow the observed trend or if they deviate from the observed water surface elevation plot, take the following

steps. First, plot the active-bed gradation data near the end of the hydrographic record on an observed bed gradation curve to determine the validity of the distribution of the inflowing sediment load by grain size. Make plots for several different times because the gradation of the bed will vary with the inflowing sediment load. This will reveal any nonrepresentative gradations in the inflowing load. Correct any inconsistancies in these data and try another run. If the problem persists, check the field data for possible rock outcroppings and check calculated profiles for any possible errors in nearby sections. If no corrective action results at this point, check top bank elevations or, if calculated results are too high, check prototype data for a gravel deposit, which could result in an armor layer problem.

Finally, if none of the above actions produce an acceptable performance, then change the inflowing sediment load. Use a constant ratio to translate the curve without rotation.

DEVELOPMENT OF BASE TEST AND ANALYSIS OF ALTERNATIVES

A river mechanics simulation model such as HEC-6, is best used to predict the differential impacts of various project alternatives among themselves and compared to a base case. In most cases the base case is the simulated behavior of the river under existing conditions, or those conditions that existed prior to construction of any dams or structures along the river. For example, in a proposed reservoir study, the base case would be without the reservoir or dam in place. In most cases, the base case simulation should show little net scour or deposition. This assumes that the river is near equilibrium (where scour approximately equals deposition) under existing conditions and would remain in this condition in the future if the project were not constructed.

Having established and run a base test, the project alternatives can be simulated by modifying the data set appropriately. For a channel improvement project, cross-sectional geometry can be changed to reflect the changed condition. A dam can be simulated with special data cards described in the users manual. Avoid major changes to the geometry because the calibration may become difficult. If a major change is contemplated, make the evaluation in steps. Avoid changing more than one parameter at a time because it makes the results difficult to interpret. Model results should be used only as an aid in predicting future conditions; rely on engineering judgement and subject any unexpected response of the model to careful scrutiny. These "surprises" can be used by the experienced river engineer to locate data inadequacies and better understand the behavior of the prototype system.

Model results should be interpreted by comparison with the base case results. Results should be presented in terms of change from the base case wherever possible. This will provide an assessment of the impacts of proposed projects.

It is usually desirable during the course of a study to perform a sensitivity test. Quite often certain input data (such as inflowing sediment load) are not available, or might be subject to substantial measurement error. The impact of these uncertainties on model results can be studied by modifying the suspected input data by $\pm$ x % and rerunning the simulation. If little change in the simulation results, the uncertainty in the data is of no consequence. If large changes occur, the input data needs to be refined. Refinement should then proceed using good judgement and by modifying only one parameter or quantity at a time so as to be able to see the exact effect that overall changes may have.

Sensitivity studies performed in this manner will most likely provide good sound insight into the prototype's behavior and will lead to the best model description of the real system.

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Computer program HEC-6, "Scour and Deposition in Rivers and Reservoirs" is a one dimensional steady state simulation model designed to analyze long-termed scour and deposition in rivers and reservoirs. The program considers the interactions between water and suspended sediment, the sediment material in the bed and the hydraulics of the flow. Procedures for calibrating and applying HEC-6 to river and reservoir sediment studies are discussed. Some of the topics discussed in here include development of representative geometric and hydrologic data, preparation (CONTINUED)

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